Land Use Modeling at H-GAC

Dmitry Messen
Houston Galveston Area Council

Presentation

- An overview of the H-GAC's operational (2006-release) land use forecasting model
- An overview of the H-GAC's new (under development) land use forecasting model
- Conceptual and practical issues in integrating land use and travel demand models

H-GAC Forecasting Model

- Phase I: County-level Forecast
  - Population (by age-race)
  - Households (by race-size)
  - Employment (by sector)
- Phase II: Small-Area Allocation
  - UrbanSim Land Use Forecasting Model
- Phase III: TAZ-level Summary
  - Households (by race-size-income)
  - Employment (by sector)

Regional Growth

- What is “regional growth”?
  - More people, more jobs
  - More buildings (net positive change in stock)
  - Availability of buildings is a necessary (but not sufficient) condition for population and employment growth
  - Geography of buildings = geography of population and employment
  - To model where development will happen = to model where the population and employment growth will happen

Agent-based Modeling

- Deriving aggregate system results from the behavior of the individuals (agents) rather than modeling the aggregate behavior itself
- Quantum approach: “macro” outcomes are formed by cumulating “micro” actions
- Our “quanta”: individuals (utility-maximizing) making choices
  - People (households): where to live (housing choices)
  - Employers: where to put employees (job location choices)
  - Developers/land owners: what to build and where to build it (development choices)
  - All choices are constrained and outcomes are probabilistic

Theoretical Foundations From Economics

- Supply-demand; equilibrium; short run-long run; utility maximization
- Primary real estate market (new buildings)
- Supply side: developers (producers of buildings)
- Demand side: households, employers (consumers of buildings)
- Short-run inelastic supply (here’s what we have now…)
- Long-run supply adjustment (inertia and long production cycle)
- Dynamic disequilibrium between supply and demand
- Constrained choices; high transaction costs

Agent-based Modeling In UrbanSim

- UrbanSim models the real world by
  - Defining (explicitly) demand-side agents (individual households and jobs)
  - Defining (implicitly) supply-side agents (developers)
  - Defining the environment (stock of available housing units and job slots, physical and planning development constraints)
  - Defining the probabilistic behavior rules (preferences, constraints, and development patterns)
  - Defining total regional demand in the future (control totals)
  - Setting up a Monte-Carlo simulation
- And then it coordinates all these moving parts into producing a small-area forecast of population and employment.

At the beginning of a model year, we know the characteristics of…

- Housing units and buildings where people live and work (locations, type, value)
- Households (location, composition, income).
- Jobs (location, type)
- Transportation system (cost of travel, travel times)

During A Model Year…

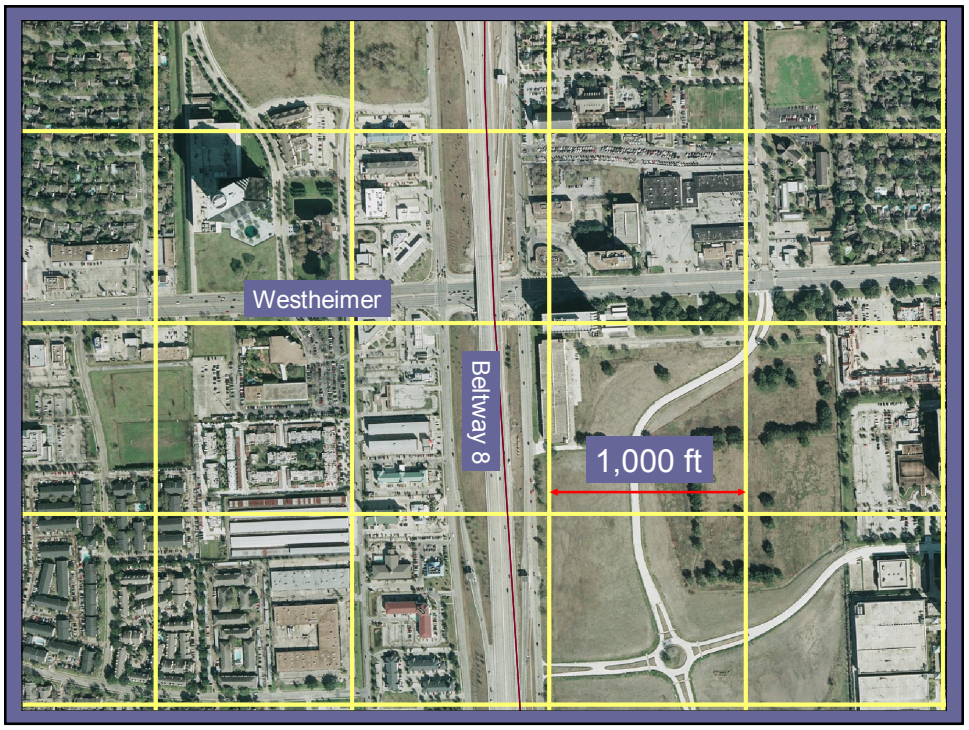
- Developers build buildings
- People and households change (birth, death, marriage, aging, migration)
- Jobs change (new jobs created, some old jobs removed)
- Some households look for housing and select from available stock
- Some employers look for “job spaces” and select from available stock

At The End Of A Model Year…

- For transportation planning:
  - Incremental change in the distribution of population and employment
  - Incremental change in traffic conditions
- For regional planning:
  - Incremental change in demand for services

UrbanSim's Anatomy—Base Year

- User-Defined Regular Grid
  - 1,000 by 1,000 ft (23 acres; 28 grid cells per sqm)
  - Close to 250,000 grid cells
- Grid Attributes
  - Number of housing units; com-ind-gov. sq. footage
  - Value of residential and com-ind-gov improvements
  - Proximity to highways, arterials (from current and future networks)
  - Physical features (% water, % open space, etc.)
  - Other (GRID_ID, land use (development) type)
- TDM data
  - Inter-TAZ logsums (proxy for relative costs)
  - Travel time to airport, CBD



UrbanSim's Anatomy—Base Year (cont.)

- Households
  - Table with individual households (household_id)
  - Attributes: GRID_ID, size (# of people), race, age (of household head) income, # of cars, # of workers
- Jobs
  - Table with individual jobs (job_id)
  - Attributes: GRID_ID, sector (7 sectors; user-defined)
    - Durables, Non-Durables, Mining, CTPU, FIRE-Services, Retail-Wholesale, Gov-Med-Ed

Base Year Data Sources

- County appraisal (housing units, non-residential sq footage, value of improvements)
- Info-USA (company-level data on location, sector, # of employees)
- Census (household attributes)
  - Household "synthesis": use marginal probabilities from PUMS to disaggregate block group-level SF-3 data
- Transportation (logsums, networks)
- Other (satellite and aerial imagery, proprietary real estate databases, research)

UrbanSim Sub-Models (Modules)

- Accessibility
- Household transition
- Employment transition
- Household (re)location choice
- Employment (re)location choice
- Land price
- Developer

Annual Sequence

1. Accessibilities are “announced” (computed)
2. Households are created/removed
3. Jobs are created/removed
4. New households “select” from the stock of available housing units
5. New workers “select” from the stock of available job spaces (1 job space = X sq ft)
6. Market “announces” new land values (computed)
7. Developers build new housing units and non-residential sq. footage
    - Supply gets intelligence on demand

Accessibility

- Uses logsums to compute accessibility to housing, employment, different land uses, recent developments
- Conveys information about the
  - Spatial distribution of housing and jobs
  - Disutility (cost) of travel
  - Transportation network
- Computed for every grid cell, for every activity
- Exponential distance (cost) decay function
- One of the LU-T links

Household Transition

- Simulates aggregate results of family dynamics
- “Updates” (removes/creates) current households to match the target (control total)
- Creates vacant units (when a household is removed)
- Puts “unplaced” (newly created) households (GRID_ID=0) in a buffer

Employment Transition

- Simulates aggregate results of employment dynamics
  - New jobs created, old jobs terminated
- "Updates" (removes/creates) current jobs to matches the target (control total)
- Creates vacant slots (when a job is removed)
- Puts "unplaced" (newly created) jobs (GRID_ID=0) in a buffer

Household Location Choice

- Simulates household decisions on where to reside
- Applies to "unplaced" households
- Selection from a stock of available housing
- Procedure:
  - Group unplaced households by attributes
  - Sample available locations
  - Assign probabilities (from multinomial logit model)
    - Cost/income ratio, access to employment, housing within walking distance
  - Use Monte Carlo sampling to pick location and assign GRID_ID

Employment Location Choice

- Simulates employer decisions on where to locate jobs
- Applies to “unplaced” jobs
- Selection from a stock of available job slots
- Procedure:
  - Group unplaced jobs by sector
  - Sample available locations
  - Assign probabilities (from multinomial logit model)
    - Land use types, proximities, access to emp, pop
  - Use Monte Carlo sampling to pick location and assign GRID_ID

Multinomial Logit Model (Household and Employment Location Choice)

- Ideally: a sample of newly located businesses and households
- In reality: sample of existing businesses and households

Re-location

- Household relocation module
- Employment relocation module
- User-specified % of households, jobs wishing to change location
- Puts households, jobs in a buffer and releases houses units, job slots
- Not used

Land Price

- Simulates the determination of land values by the market
- Parameters from hedonic regression (OLS)
  - Within walking distance: average residential unit value, number of residential units, total employment
  - Dummy variables for development types

Developer

- "Site" looking for "use"
- Simulates decision made by land owners/real estate developers
- Creates new residential units and non-residential sq. footage
- Most important module
  - Households/employment locate only in available housing/space
- Development types (for grid cells)
  - Min, max (units, sq footage)
  - 8 residential, 8 mixed, 3 commercial, 3 industrial, 1 gov, 1 vacant, 1 undevelopable

Development Types

DEVELOPMENT_TYPE_ID	NAME	MIN_UNITS	MAX_UNITS	MIN_SQFT	MAX_SQFT	PRIMARY_USE_ID
1	R1	1	10	0	6,000	1
2	R2	11	40	0	6,000	1
3	R3	41	80	0	6,000	1
4	R4	81	140	0	25,000	1
5	R5	141	200	0	25,000	1
6	R6	201	300	0	25,000	1
7	R7	301	600	0	40,000	1
8	R8	601	10,000	0	40,000	1
9	M1	1	80	6,001	40,000	1
10	M2	81	300	25,001	40,000	1
11	M3	81	300	40,001	100,000	1
12	M4	81	300	100,001	300,000	2
13	M5	81	300	300,001	10,000,000	2
14	M6	301	10,000	40,001	80,000	2
15	M7	301	10,000	80,001	240,000	2
16	M8	301	10,000	240,001	10,000,000	2
17	C1	0	80	40,001	250,000	3
18	C2	0	80	250,001	1,000,000	3
19	C3	0	80	1,000,001	20,000,000	3
20	I1	0	80	40,001	250,000	4
21	I2	0	80	250,001	1,000,000	4
22	I3	0	80	1,000,001	10,000,000	4
23	GV	0	80	40,001	20,000,000	5
24	VA	0	0	0	0	6
25	UN	0	0	0	10,000,000	7

Transitions

- "Transitions" define development rules
- Transitions
  - Within the same dev type
  - From one type to another
  - Only certain transitions are allowed (user-defined)

FROM	TO
1	2
2	3
3	4
3	9
3	17
9	9
17	14
17	17
18	18

Transitions (cont.)

- Roll-back procedure
  - Current appraisal data with year of construction for buildings
  - Roll the time back and reconstruct past land use (quantities of housing units and non-residential square footage)
  - Identify development types to go into the transition table
  - Derive parameters for the distribution

Transitions (cont.)

- Transition probability estimation
  - Multinomial logit
  - Choice set includes no-build alternatives
  - P is a function of grid cell's and local attributes
    - Recent transitions, land value, % open space
  - Sampling setup
    - Artificial observation with 5 alternatives (1 transition)
    - Different grid cells
  - Calibration (frequency of transitions)

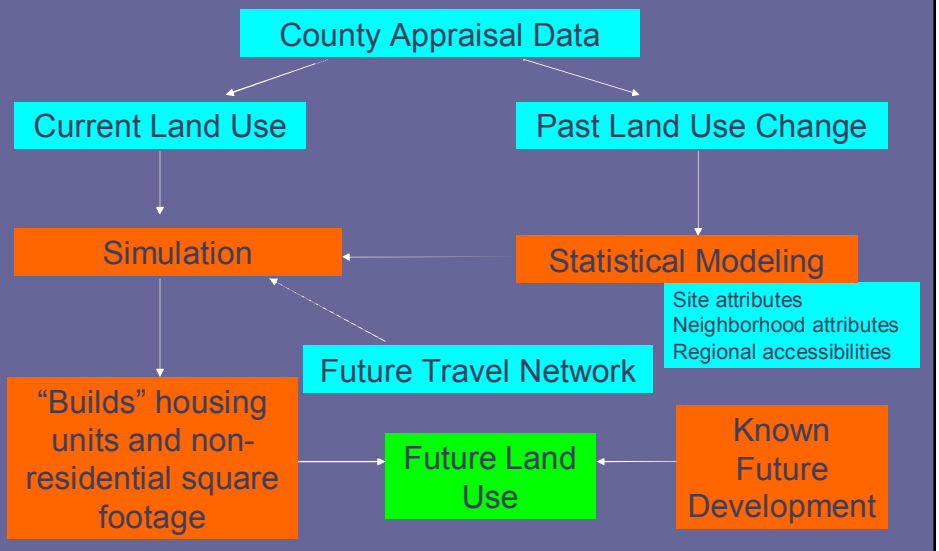
Developer Model

- Simulation
  - Apply constrains (exclude certain grid cells)
  - Determine build or NO build
  - If build, then determine quantities
    - Distribution for new construction (min, max, mean, std)
  - Vacancy adjustment
    - Speed up development if vacancy is low, slow down if vacancy is high

Events

- Deterministic component
- Under construction or planned (known or likely to occur)
- Grid-specific
- Development events
- Employment events (not used)
- Land use events (not used)

UrbanSim Land Use Forecasting Model

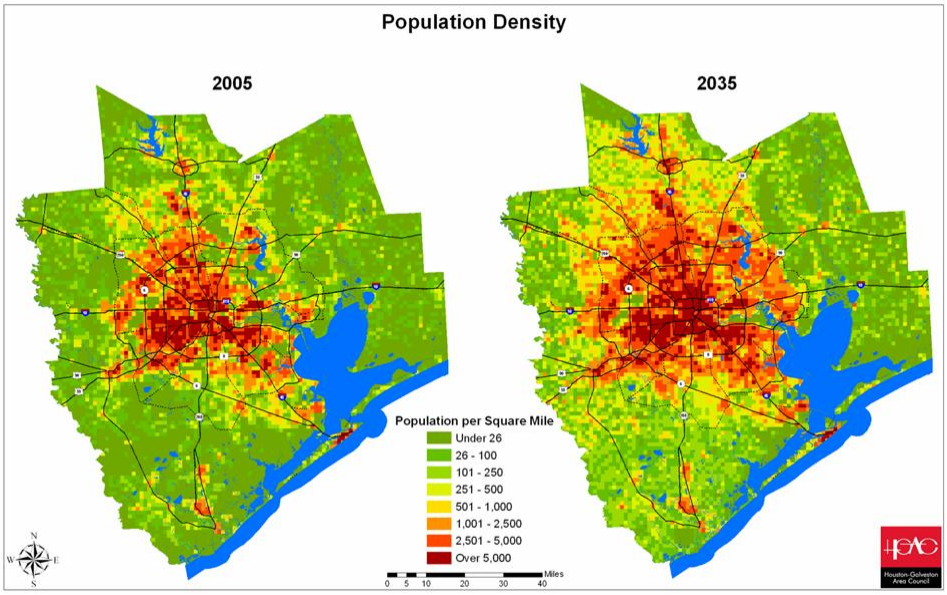


Running UrbanSim

- UrbanSim “scenario” (instructions) file
- Specify the forecast horizon
- Specify years to output
- UrbanSim reports future grid cell conditions
- Aggregate from grid cells to TAZ
  - Households (by attributes)
  - Jobs (by sector)
- Give results to transportation modeling group

UrbanSim Workflow

- Assemble data (base year and control totals)
- Run the “consistency checker” utility
- Run the “estimation data writer” utility
  - Prepares data for statistical modeling
  - Develop specification and estimate parameters (SAS)
    - Art/science, no general solution
  - Populate UrbanSim tables (model specification and coefficients)
- Run the simulation
- Tabulate and map results



Shortcomings

- Development type – a statistical construct
- Sq ft per job depends on development type, not employment sector
- Incomes are static, while land prices are not
- Accessibility "bias"
  - Large, unconnected tracts of land
- Modes of development
  - In-fill and accretion vs. MPC on large inaccessible tracts
- County boundaries
- Residential areas without adequate local employment (retail, services, education)
- Undifferentiated housing market (generic housing units)
- Undifferentiated job places (generic square footage)
- No job-home connection

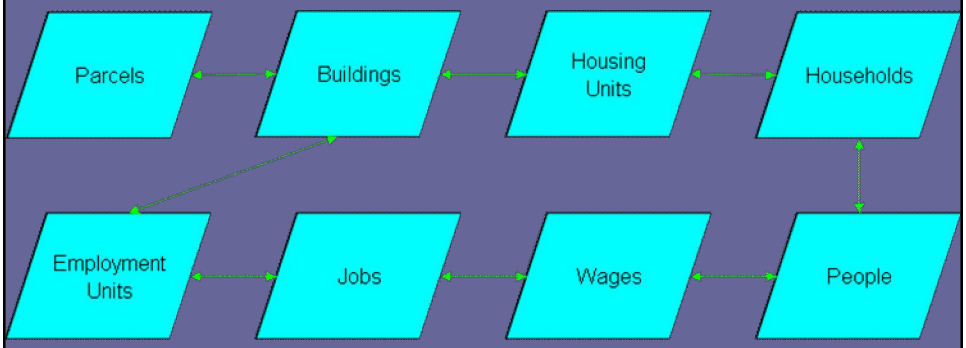
Need To Account For

- Population dynamics (birth, death, age, migration)
- Household dynamics (formation, dissolution)
- Housing preferences and constraints
- Household incomes and budgets
- Worker dynamics (earnings change with age, education)
- Home-work separation (reasonable commutes)
- Job-building match (so that retail jobs go into retail buildings)
- Household-housing unit match (cost, size, preferences)
- “Neighborhood” employment vs. Regional employment (so that new residential areas have local stores, schools, and services)
- Local amenities and non-work destinations

New Features

- Demographic transition module (not part of UrbanSim)
  - Simulation of demographic and household dynamics (aging, births/deaths, marriages/divorce, migration)
- Granularity (resolution)
  - People-households
  - Jobs
  - Buildings
  - Parcels

Links In The Future Configuration



New Features (cont.)

- Developer model creating buildings and complexes ("use" looking for "site")
- Sub-regional control totals and target vacancy rates
- Housing units segmentation (by type, size, ownership, purpose; user-defined)
- Building type segmentation (office building, large retail, small retail, school, etc; user-defined)
- Matching of household to housing units
- Matching of jobs to building types

Additional Desired Features

- "Neighborhood" jobs (and buildings) and "regional" jobs
- Worker dynamics (wage change with age, education)
- Household budgets
- Inflation
- Representation of local amenities and non-work destinations
- Separate redevelopment module
- Group quarters
- Explicit representation of mass transit and major future improvements (not just through logsums)
- Transit-oriented development (TOD)
- TDM "light" (some crude measure of flows and travel times)
- Infrastructure cost module
- Local government module (expenditures, revenues)

Advantages

- Ability to model complex scenarios
  - Alternatives to transportation investment (land use solutions; regional budgets)
  - Energy prices
  - Changing demographic structure and housing preferences
  - Global warming
  - Immigration policies
- Feedbacks
- Dynamic disequilibrium
  - Today's land use choices affect future accessibilities
  - Today's land use choices are based on today's accessibilities (or expectations of future accessibilities)

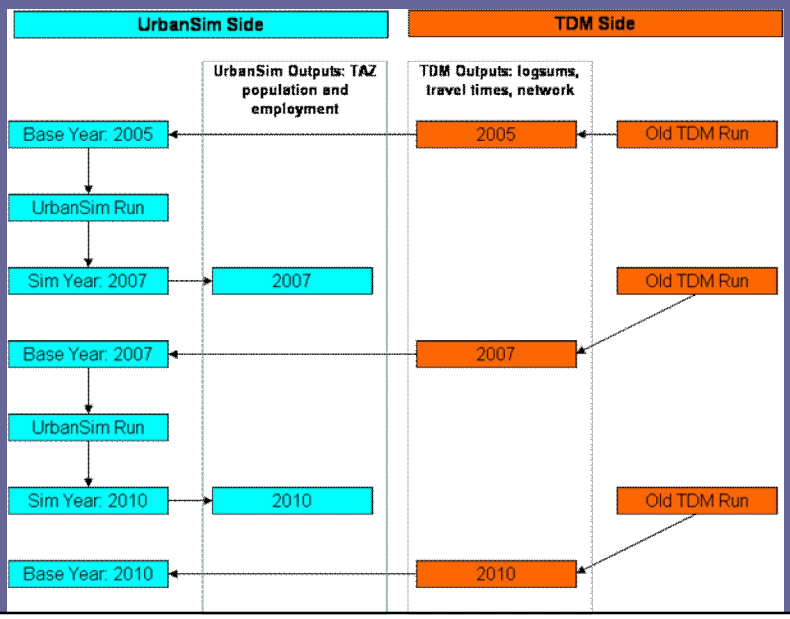
Land Use And Transportation

- How do transportation conditions (accessibilities, proximities, travel times, etc.) affect decisions made by developers, households and businesses?
- In the current setup, only demand (households and businesses) responds to transportation conditions; should supply respond too?

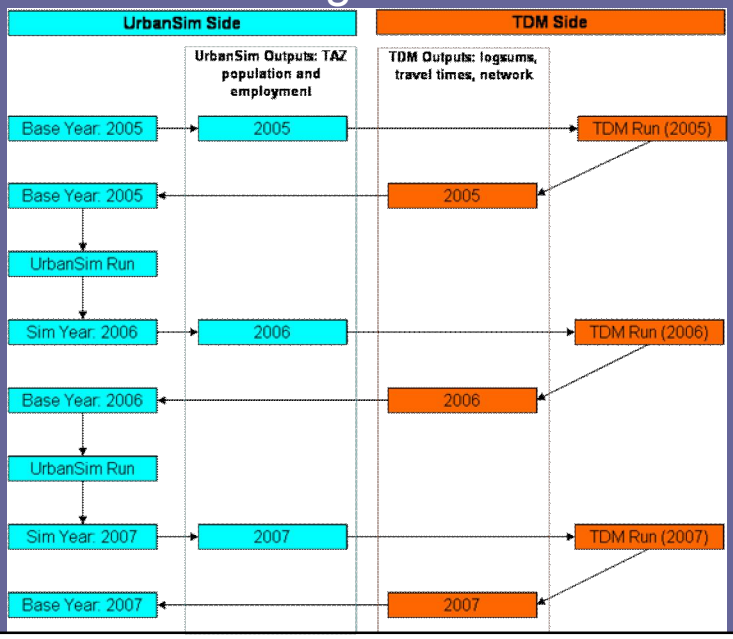
LU-TDM Integration

- Periodic forward-going feedback (information exchange) between the land use and transportation models
  - Today's land use decisions are informed by the transportation conditions of the present (or expectations)
  - Future transportation conditions are changed by today's land use decisions
- Equilibrium is impossible!
  - No "undo/redo" button
  - Path-dependence: we have to live with the consequences of our choices
- If a socioeconomic forecast is using TDM inputs, then it's TDM version-specific

UrbanSim-TDM Integration: Current Setup



UrbanSim-TDM Integration: Desired Setup



TDM Issues

- Build foundation for activity-based travel demand modeling
  - Explicit representation of commute (and other likely destinations)
  - Would not be difficult to construct daily schedules
- In a 4-step model framework
  - Move trip generation and distribution out of TDM?

Thank you!